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WIDE-BAND SINGLE HORN SYSTEM

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A simpler wide-band horn system has been studied in order to minimize operational difficulties in the present wide-band horn system[1]. In the present horn system, the upstream horn has two narrow necks in the inner conductor to provide two focussing lenses. The downstream horn has a single narrow neck to provide the third focussing lens for the present system.

The main design goals of the new system are as follows:

1. to be simple mechanically, i.e., a single horn of one lens,
2. to make the inner conductor neck relatively large so that the primary proton beam is unlikely to hit it, and
3. to give reasonable neutrino fluxes compared to the present system.

Figure 1 shows a schematic drawing of the proposed horn. The shape of the inner conductor is determined in order to focus particles of the momentum of p (GeV/c) produced at the angle of $\theta \doteq 0.3/p$ for the horn excitation current of 150 kA[2]. The narrow neck is positioned at the downstream end of the horn in order to provide a largest possible opening for a fixed polar angle of 1.2 mrad viewed from the target. This angle is chosen because the 15 foot Bubble Chamber covers the production angle of about 1 mrad within which no focussing is required. The distance between the target and the middle of the 5 m long horn is 10 m. It can focus particles of momenta greater than 20 GeV/c. If a larger opening for the inner conductor neck is required, the horn should be located further downstream and be longer proportionally to the distance from the target.

Figure 2 shows computed neutrino fluxes[3] and wrong sign backgrounds for the new single horn system and the present double horn system. Computed neutrino fluxes for the perfect focussing and bare target systems and the single horn arrangements for the present upstream and downstream horns are also shown. The incident proton energy is 400 GeV. The horn excitation current is set to 150 kA to match the average polar angle acceptance of 0.3/p for the particles of the momenta of p (GeV/c), namely the average transverse momenta of 0.3 GeV/c for particle productions. Since the excitation current is linearly proportional to the average transverse momenta of these particles which are focussed point-to-parallel in the single horn system, it is easily seen that the excitation current setting is relatively insensitive to the neutrino flux intensity, particularly for the new single horn system. Parameterization by Stefanski-White[4] is used to calculate the production cross section spectra for mesons. The radius of the effective detection area of the 15 foot Bubble Chamber is assumed 1.35 m.

Table I summarizes relative integrated neutrino event rates for the various configurations normalized to the rate which is integrated up to the neutrino energy of 250 GeV for the perfect focussing system. The total cross section for neutrino interactions is assumed to be proportional to the neutrino energy. The second column gives the total event rates (<250 GeV) and the other columns show the energy dependence of the event rates for five energy regions below 250 GeV. The proposed single horn system gives about 88% of the neutrino events produced by the present double horn system. The single horn arrangement by the upstream horn of two lenses gives similar event rates, but the downstream horn alone can give substantially low rates. The wrong sign backgrounds for the new horn system seem to be slightly worse. Major contributions of wrong sign backgrounds come from negatively charged mesons which are produced at very small angles and stay inside the inner conductors. Therefore, they are more sensitive to the dimensions of the narrow necks of the inner conductor than to the focussing properties of the horns. As will be discussed later, the most obvious and simplest solution to reduce the wrong sign backgrounds is to use a plug along the horn axis. This arrangement is particularly important for anti-neutrino runs in which the wrong sign backgrounds are large.

Figure 3 shows computed neutrino fluxes for the new single horn system and the present double horn system at the incident proton energies of 200, 300, 400, 500, 800 and 1000 GeV. Table II gives integrated event rates for the neutrino energy below 300 GeV. The total cross section for neutrino interactions is assumed to be proportional to the neutrino energy. The difference between the event rates for the two systems becomes insignificant at higher proton energies.

Figure 4 shows computed anti-neutrino fluxes and wrong sign backgrounds for the new single horn system and the present double horn system. Computed anti-neutrino fluxes for the perfect focussing and bare target systems are also shown. The wrong sign backgrounds are relatively large. Computed anti-neutrino fluxes and wrong sign backgrounds for the two systems with plugs of ±1.2 mrad and 3.3 interaction lengths are shown in Figure 5. Although the neutrino fluxes are slightly reduced, the wrong sign backgrounds are comfortably small. For the single horn system, the plug is located right after the horn, i.e., 13 m from the target. The fluxes and backgrounds for the double horn-plug system are shown for two plug positions: 1) 6 m from the target, i.e., right after the first horn, and 2) 13 m from the target, i.e. at the same location as for the single horn system. It is very advantageous to place the plug as close to the target as possible after particles go through the first horn. However, heating damage of the plug by the high energy and high intensity beam will be severe when the plug is located closer to the target.

Table III summarizes relative integrated anti-neutrino event rates normalized to the rate which is integrated up to the anti-neutrino energy of 250 GeV for the perfect focussing system. The total cross section for anti-neutrino interactions is assumed to be proportional to the anti-neutrino energy. The rates for the double horn-plug system correspond to the case in which the 1.2 mrad plug is located right after the first horn.

REFERENCES

1. F. A. Nezrick, Nuclear Science, NS-22, 1479 (1975).

2. R. B. Palmer, CERN 65-32, 141, December 1965.

3. D. C. Carey and V. A. White, Fermilab Internal Report, NUADA June 1, 1975. The NUADA program revised on April 23, 1976 has been used throughout the present study.

4. R. J. Stefanski and H. B. White, FN292, 2060.000, 1976.

TABLE I

NORMALIZED NEUTRINO EVENT RATES (%)

HORN ARRANGEMENT	ENERGY RANGES (GeV) 0 TO 250	0 TO 25	25 TO 50	50 TO 100	100 TO 150	150 TO 250
PERFECT	100.0	24.2	40.6	18.6	8.7	8.3
BARE TARGET	10.5	1.8	2.9	3.0	1.6	1.2
NEW SINGLE HORN	31.4	5.9	11.5	7.8	3.5	2.8
PRESENT DOUBLE HORNS	35.7	7.6	13.1	8.2	3.8	3.1
PRESENT UPSTREAM HORN	27.7	5.0	9.7	7.0	3.4	2.6
PRESENT DOWNSTREAM HORN	22.4	4.5	8.0	5.5	2.4	1.9

TABLE II

RELATIVE NEUTRINO EVENT RATES* FOR THE PROPOSED SINGLE HORN SYSTEM AND THE PRESENT DOUBLE HORN SYSTEM

ENERGY RANGE (GeV)	INCIDENT PROTON ENERGY (GeV)					
	200	300	400	500	800	1000
SINGLE HORN						
0 - 50	0.18	0.34	0.48	0.59	0.75	0.78
50 - 100	0.03	0.11	0.22	0.34	0.68	0.85
100 - 300	0.01	0.07	0.18	0.34	0.92	1.36
0 - 300	0.22	0.53	0.88	1.26	2.35	3.00
DOUBLE HORNS						
0 - 50	0.24	0.43	0.57	0.68	0.83	0.86
50 - 100	0.04	0.12	0.23	0.35	0.70	0.86
100 - 300	0.02	0.08	0.20	0.36	0.95	1.36
0 - 300	0.30	0.62	1.00	1.39	2.48	3.09
Ratio of Event Rates of SINGLE HORN to DOUBLE HORNS 0 - 300	0.77	0.84	0.88	0.91	0.95	0.97

* Event rates are normalized to the rate for the present double horn system in the neutrino energy range between 0 and 300 GeV.

TABLE III

NORMALIZED ANTI-NEUTRINO EVENT RATES (%)

HORN ARRANGEMENT	ENERGY RANGES (GeV) 0 TO 250	0 TO 25	25 TO 50	50 TO 100	100 TO 150	150 TO 250
PERFECT	100.0	36.7	44.9	13.7	3.4	1.3
BARE TARGET	7.9	2.4	2.9	1.9	0.5	0.2
NEW SINGLE HORN (NO PLUG)	27.5	8.1	12.2	5.5	1.2	0.4
PRESENT DOUBLE HORNS (NO PLUG)	32.6	10.9	14.0	5.9	1.4	0.5
NEW SINGLE HORN (PLUG)*	21.5	7.0	9.5	3.8	0.9	0.3
PRESENT DOUBLE HORNS (PLUG)*	21.2	8.0	8.9	3.2	0.8	0.3

* The 1.2 mrad plug for the new single horn system is located right after the horn, i.e., 13 m from the target. For the double horn system, the 1.2 mrad plug is located right after the first horn, i.e., 6 m from the target.

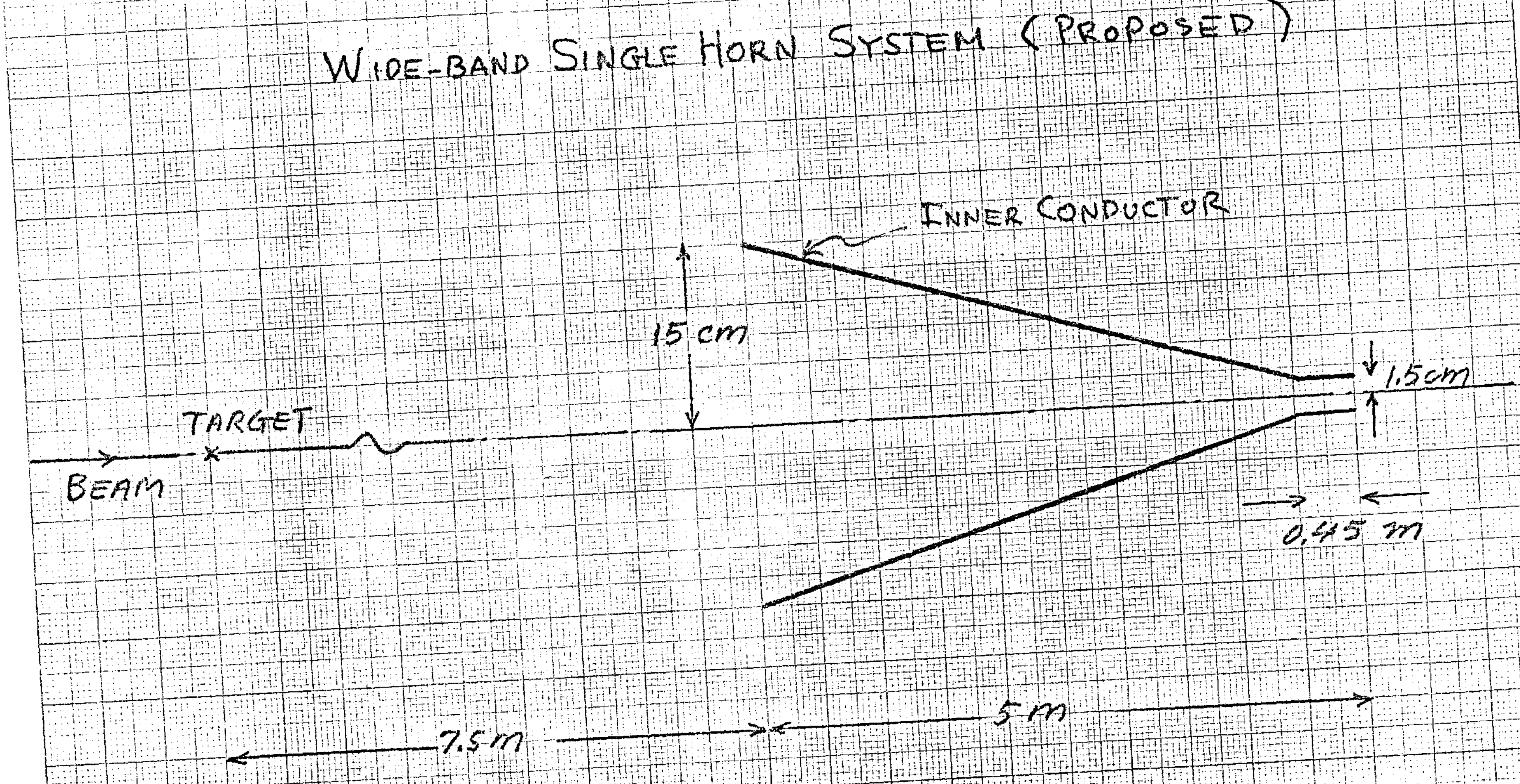
WIDE-BAND SINGLE HORN SYSTEM (PROPOSED)
INNER CONDUCTOR
15 cm
1.5cm
TARGET
BEAM
0.45 m
7.5 m
5 m

FIGURE 1

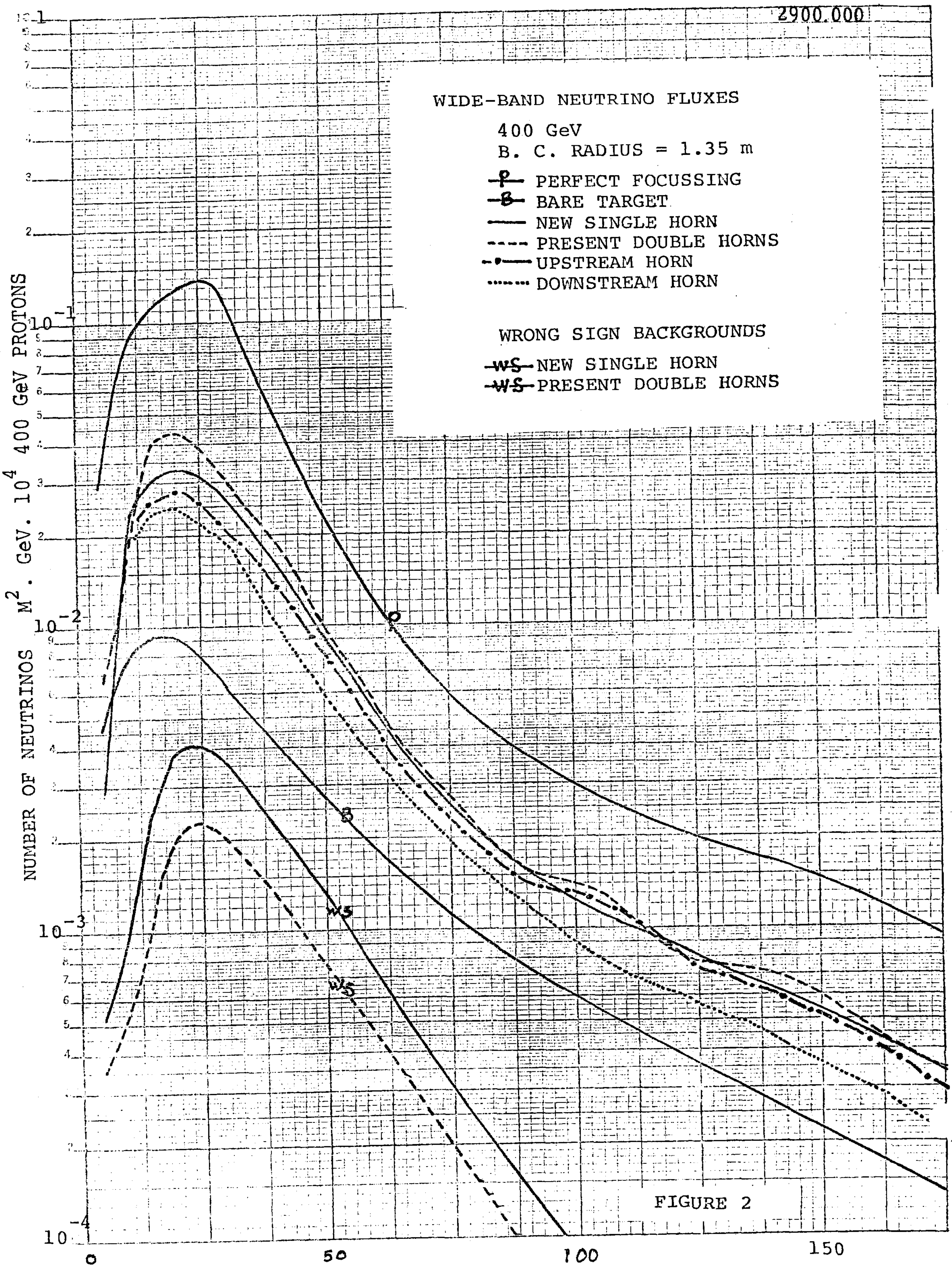
2900.000
WIDE-BAND NEUTRINO FLUXES
400 GeV
B. C. RADIUS = 1.35 m
P PERFECT FOCUSSING
B BARE TARGET
NEW SINGLE HORN
PRESENT DOUBLE HORNS
UPSTREAM HORN
DOWNSTREAM HORN
WRONG SIGN BACKGROUNDS
WS NEW SINGLE HORN
WS PRESENT DOUBLE HORNS
NUMBER OF NEUTRINOS M^2. GeV. 10^4 400 GeV PROTONS
10^{-1}
10^{-2}
10^{-3}
10^{-4}
P
B
WS
WS
0
50
100
150

FIGURE 2

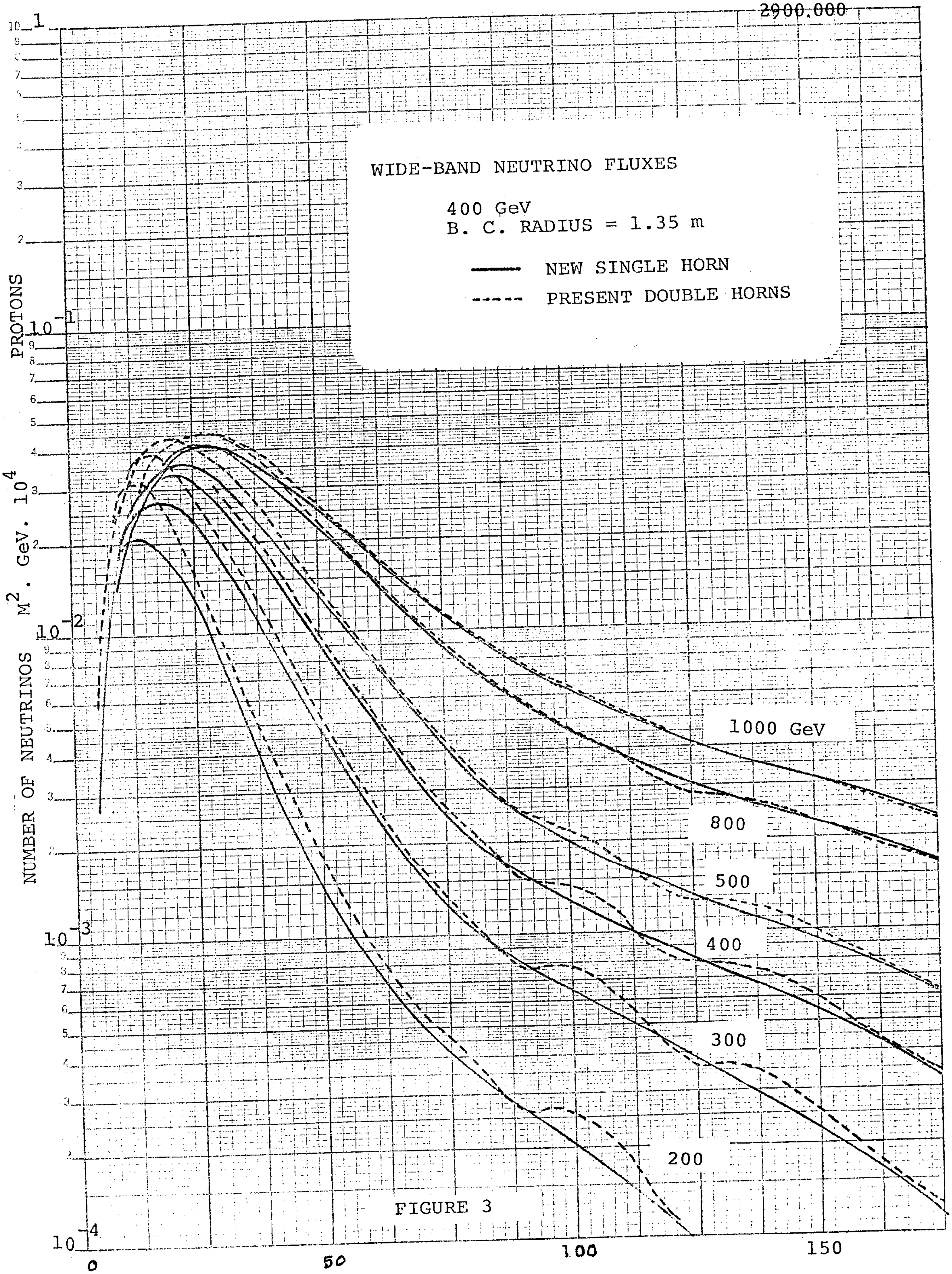
WIDE-BAND NEUTRINO FLUXES
400 GeV
B. C. RADIUS = 1.35 m
NEW SINGLE HORN
PRESENT DOUBLE HORNS
NUMBER OF NEUTRINOS M² . GeV . 10⁴ PROTONS
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
1000 GeV
800
500
400
300
200
0
50
100
150

FIGURE 3

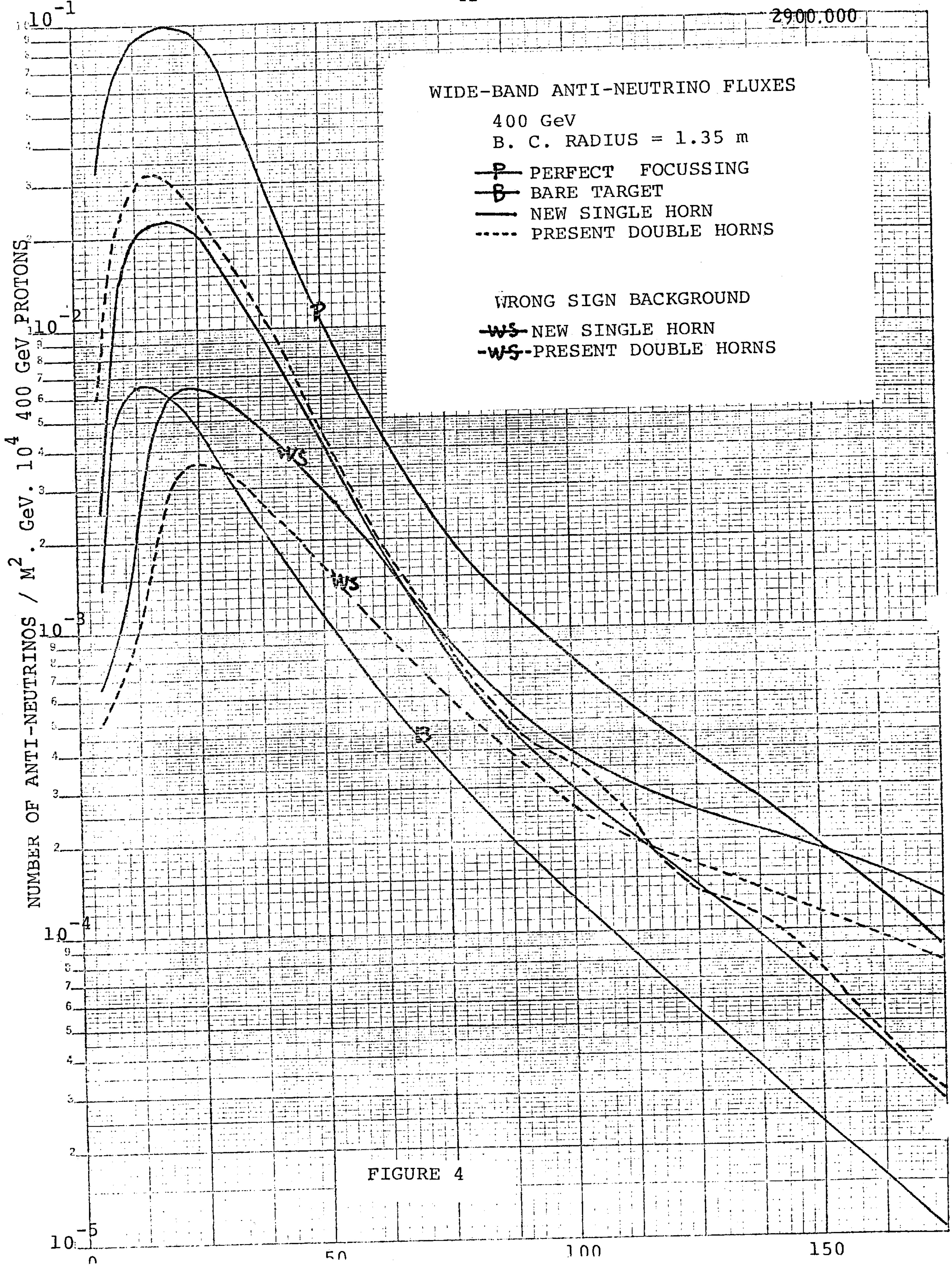
WIDE-BAND ANTI-NEUTRINO FLUXES
400 GeV
B. C. RADIUS = 1.35 m
P PERFECT FOCUSSING
B BARE TARGET
NEW SINGLE HORN
PRESENT DOUBLE HORNS
WRONG SIGN BACKGROUND
WS NEW SINGLE HORN
WS PRESENT DOUBLE HORNS
NUMBER OF ANTI-NEUTRINOS / M^2. GeV. 10^4 400 GeV PROTONS
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
50
100
150
P
WS
WS
B

FIGURE 4

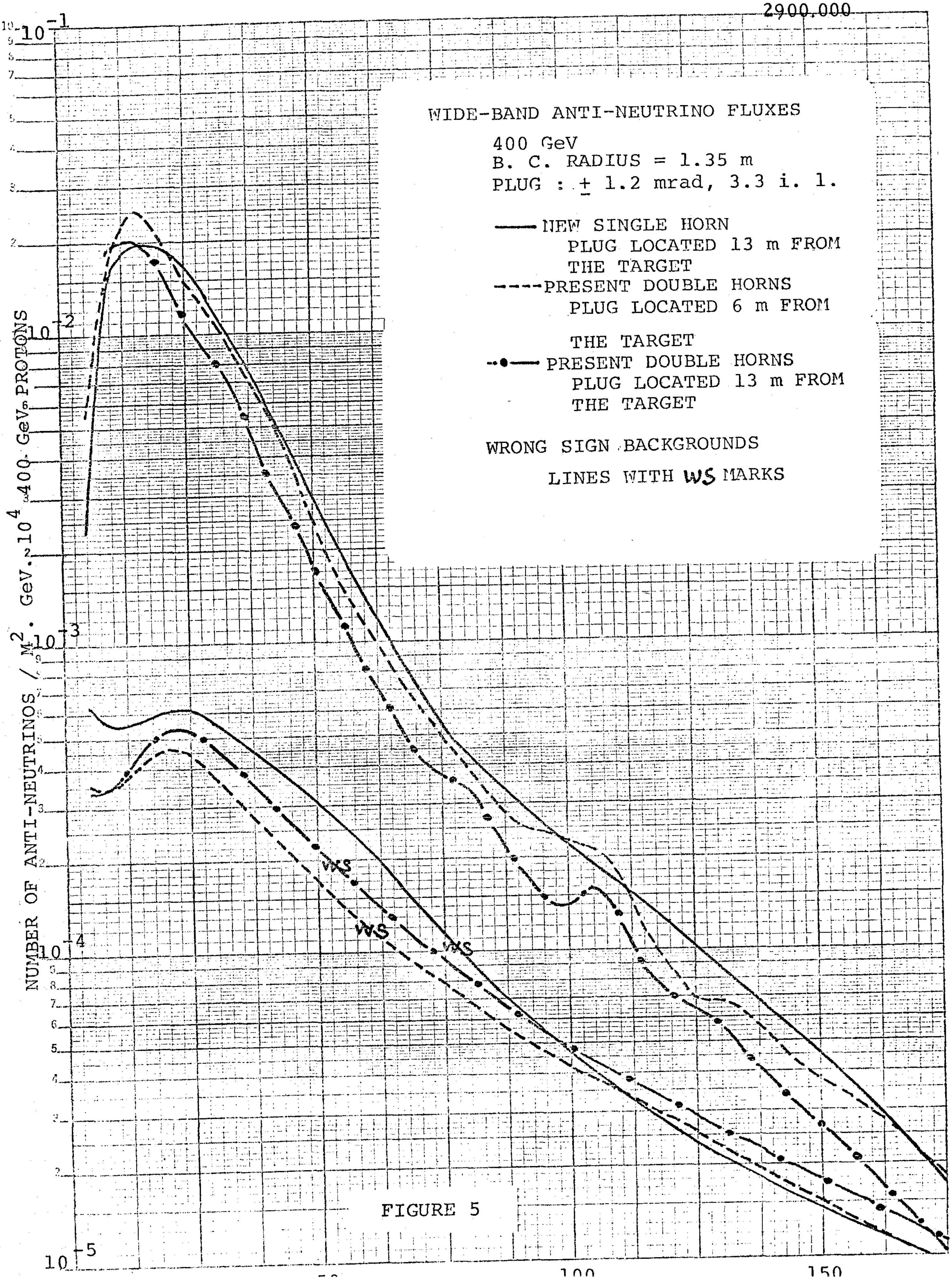
WIDE-BAND ANTI-NEUTRINO FLUXES
400 GeV
B. C. RADIUS = 1.35 m
PLUG : ± 1.2 mrad, 3.3 i. l.
NEW SINGLE HORN PLUG LOCATED 13 m FROM THE TARGET
PRESENT DOUBLE HORNS PLUG LOCATED 6 m FROM THE TARGET
PRESENT DOUBLE HORNS PLUG LOCATED 13 m FROM THE TARGET
WRONG SIGN BACKGROUNDS
LINES WITH WS MARKS
WS
WS
WS
NUMBER OF ANTI-NEUTRINOS / M2 . GeV . 10 4 400 GeV PROTONS
10-1
10-2
10-3
10-4
10-5
100
150

FIGURE 5